**Corso di studi: WBE-LM BIONICS ENGINEERING (Corso di Laurea Magistrale)**

**2016**

## Piani di studio

Biorobotics

Neural Engineering

## Biorobotics

### Primo anno

Applied brain science (12 cfu)
Bioinspired computational methods (12 cfu)
Biomechanics of human motion (6 cfu)
Materials and instrumentation for bionics engineering (12 cfu)
Statistical Signal Processing (6 cfu)
12 cfu a scelta nel gruppo Free choice

### Secondo anno

Final examination (15 cfu)
Human and animal models in biorobotics (6 cfu)
Lab Training (3 cfu)
Prosthetics and rehabilitation robotics (12 cfu)
Robotics for assisted living (12 cfu)
Robotics for surgery and targeted therapy (12 cfu)

## Neural Engineering

### Primo anno

Applied brain science (12 cfu)
Bioinspired computational methods (12 cfu)
Biomechanics of human motion (6 cfu)
Materials and instrumentation for bionics engineering (12 cfu)
Statistical Signal Processing (6 cfu)
12 cfu a scelta nel gruppo Free choice

### Secondo anno

Bionic senses (6 cfu)
Final examination (15 cfu)
Integrative cerebral function and image processing (12 cfu)
Lab Training (3 cfu)
Neural prostheses (12 cfu)
Social robotics and affective computing (12 cfu)

## Attività formative

### Applied brain science (12 Cfu)

- Cfu: 12
- Obiettivi formativi: This course is divided in two modules “Behavioral and cognitive Neuroscience” and “Computational neuroscience” In the class “Behavioral and cognitive neuroscience” the student will learn the following topics: the neurobiological correlates of human behavior and cognition; genetic factors that affect behaviour; brain mechanisms that modulate social behaviour such as emotion and aggression; the neural bases of free will; abnormal expressions of aggressive behaviour;the mental representation of the external world; the functional neuroanatomy of perception; mental representation in the absence of visual experience; pharmacological and non-pharmacological modulation of brain activity; brain enhancement; the in vivo examination of the cerebral correlates of mental function in humans; decoding neural activity: implications for the development of brain-computer interfaces. The objectives of “Computational neuroscience” class include architectures and learning methods for dynamical/recurrent neural networks and their properties analysis, bio-inspired neural modelling, spiking neural networks, the role of synaptic delays in a computational brain, the role of astrocytes in a computational brain, neuron-astrocyte networks, the role of computational neuroscience in robotics applications.
- Modalità di verifica finale: for Behavioral and cognitive neuroscience: Oral exam for Computational neuroscience: Written and Oral exam
- Propedeuticità e obblighi di frequenza : None

- Semestre: Annuale

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Behavioral and cognitive neuroscience | 6 | 60 | Da definire |
| Computational neuroscience | 6 | 60 | ALESSIO MICHELI (10532) |

### Bioinspired computational methods (12 Cfu)

- Cfu: 12
- Obiettivi formativi: The course aims to introduce the main concepts and techniques used in bioinspired computational methods. The course is divided in two modules “Neural and fuzzy computation” and “Biological data mining”. The first module intends to offer students the opportunity to learn the basic concepts and models of computational intelligence, to have a thorough understanding of the associated computational techniques, such as artificial neural networks, fuzzy systems and genetic algorithms, and to know how to apply them to a wide variety of application areas. The second module will

focus on the basic aspects of biological data mining: data pre-processing, frequent pattern mining, classification, prediction, clustering and outlier detection.
- Modalità di verifica finale: Oral exam + Lab project
- Propedeuticità e obblighi di frequenza : None

- Semestre: Annuale

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Biological data mining | 6 | 60 | FRANCESCO MARCELLONI (08716) |
| Neural and fuzzy computation | 6 | 60 | BEATRICE LAZZERINI (05933) |

**Biomechanics of human motion (6 Cfu)**

- Cfu: 6
- Obiettivi formativi: The objectives of this course are to provide an introduction to the biomechanics of the human movements and then to understand the main role underlying the control of spatial multiple degree-of-freedom human motion. These objectives will be reached by means of both theoretical lessons and practical activities in a lab of human movement analysis.
- Modalità di verifica finale: Written and oral exams
- Propedeuticità e obblighi di frequenza : None

- Semestre: Primo semestre

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Biomechanics of human motion | 6 | 60 | 26006 MONACO VITO (PC) |

**Bionic senses (6 Cfu)**

- Cfu: 6
- Obiettivi formativi: The course “Bionic senses” refers to engineering artificial sensing and perceptual systems through biological principles to implement neuroprostheses to restore lost functions, for human augmentation and bioinspired perceptional machines. The basis of needed methodology and technology will be given tutorially.
- Modalità di verifica finale: oral exam
- Propedeuticità e obblighi di frequenza : None

- Semestre: Secondo semestre

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Bionic senses | 6 | 60 | DANILO EMILIO DE ROSSI (05852) |

**Economic assessment of medical technologies and robotics for healthcare (6 Cfu)**

- Cfu: 6
- Obiettivi formativi: The course will provide the rationale and the technical tools for assessing the economic, social, usability, and acceptability dimensions of a new medical technology. The methodologies gained will enable students to assess a new medical technology both during the R&D process and in the pre-marketing phase, increasing the probability of its successful transfer and adoption in the market. A special focus will be devoted to robotics for healthcare.
- Modalità di verifica finale: written exam
- Propedeuticità e obblighi di frequenza : None

- Semestre: Secondo semestre

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Economic assessment of medical technologies and robotics for healthcare | 6 | 60 | 13571 TURCHETTI GIUSEPPE (PC) |

**Electronics for Bionics Engineering (6 Cfu)**

- Cfu: 6
- Obiettivi formativi: The student who successfully completes the course will be able to demonstrate a solid knowledge of the main issues related to the design of sensor based electronic systems for bionics engineering. He or she will acquire the ability to master trade-offs to map sensor signal processing (sensor data acquisition, conditioning and data fusion) into mixed-signal microelectronics architectures according to main performance metrics (area, speed, power consumption, flexibility, cost and time-to-market). He or she will have the opportunity to practically experience the overall design flow from specification to rapid prototyping for relevant sensor conditioning electronics by exploiting state-of-the-art computer aided design tools and FPGA technologies.
- Modalità di verifica finale: Oral exam and practical projects
- Propedeuticità e obblighi di frequenza : None

- Semestre: Secondo semestre

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Electronics for Bionics Engineering | 6 | 60 | LUCA FANUCCI (10900) |

**Final examination (15 Cfu)**

- Cfu: 15
- Obiettivi formativi: The final examination involves the preparation of a report led to a design or research activity, and in its presentation and discussion.
- Modalità di verifica finale: The final examination involves the preparation of a report led to a design or research activity, and in its presentation and discussion . The evaluation of the work, as well as on the quality of the work , will be based on the mastery of the analyzed topics, the ability to work autonomously on attitudes of synthesis and communication skills
- Propedeuticità e obblighi di frequenza : None

**Human and animal models in biorobotics (6 Cfu)**

- Cfu: 6
- Obiettivi formativi: The course focuses on bioinspired robotics and biorobotic platforms for neuroscience and biology. The course provides the knowledge about the models of the human brain, of human intelligence, of muscle-skeletal systems, and of perceptual systems that are relevant in biorobotics. The students will learn principles of bioinspiration and biomimetics in robotics and the design methods and the technical tools for implementing such brain models and other animal models in robots. The students will have the opportunity to challenge themselves in their own design of robots inspired to functional mechanisms of human beings and other animals. Where appropriate, hands-on activities and student projects will be included in the course.
- Modalità di verifica finale: Oral exam
- Propedeuticità e obblighi di frequenza : None

**Integrative cerebral function and image processing (12 Cfu)**

- Cfu: 12
- Obiettivi formativi: The course is divided in two modules: Integrative cerebral functions – All cognitive and emotional functions are the by-product of the activity of anatomo-functional distributed and, at the same time, integrated networks. The didactic module entitled "Integrative cerebral functions" will address the following main topics: 1) Node and rich-clubs in the human connectome; 2) Sleep, mentation and dreaming; 3) Biological bases of consciousness; 4) Theory of mind and mirror neuron system; 4) Empathy in the emotional context; 5) Stress in the context of body and mind integration Advanced image processing - This module will cover advanced image processing methods that can be applied to biomedical images of the brain. In particular, the methods used to study structural and functional connectivity, as well as brain metabolism, will be deeply covered. The students will be trained to process images acquired using different neuroimaging techniques, as those based on MRI, PET and NIRS. The course will also introduce the main approaches for the integration of biomedical images and electrophysiological recordings.
- Modalità di verifica finale: Integrative cerebral functions – Written and oral exam Advanced image processing – Written computer based and oral exam.
- Propedeuticità e obblighi di frequenza : None

- Semestre: Annuale

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Integrative cerebral function | 6 | 60 | ANGELO GEMIGNANI (09766) |
| Advanced image processing | 6 | 60 | Da definire |

**Lab Training (3 Cfu)**

- Cfu: 3
- Obiettivi formativi: This activity will consist of Lab training that the student will perform in dedicated facilities and laboratories, with the aim to increase his/her experience in laboratory practice.
- Modalità di verifica finale: Oral Exam
- Propedeuticità e obblighi di frequenza : None

- Semestre: Secondo semestre

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Lab Training | 3 | 30 | LUIGI LANDINI (05801) |

**Materials and instrumentation for bionics engineering (12 Cfu)**

- Cfu: 12
- Obiettivi formativi: The course “Materials and instrumentation for bionics engineering” is composed of two modules: “Instrumentation and measurement for bionic systems” and “Soft and smart materials”. Instrumentation and measurement for bionic systems introduces to the methods and technologies involved in the development of equipment for measuring physical and electrical variables during monitoring and control of bionic systems. The students will be exposed to a system-oriented approach to the theory and practice of bionic measurement systems, cutting across several disciplines, including electronics, systems theory, digital signal processing, statistics and artificial intelligence. Soft and smart materials aims at providing an advanced knowledge on novel soft and smart materials for bionics. Different technologies will be analysed from the basic principles to their exploitation as smart sensors or actuators. The course will enable the student to implement a comparative analysis for the choice of the most suitable technologies for specific engineering problems. The student will be asked to use advanced design principles and tools (like CAD and FEM) as well as to carry out hands-on lab activities.
- Modalità di verifica finale: Written and oral exams
- Propedeuticità e obblighi di frequenza : None

- Semestre: Annuale

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Soft and smart materials | 6 | 60 | 26005 CIANCHETTI MATTEO (PC) |
| Instrumentation and measurement for bionic systems | 6 | 60 | 25972 SABATINI ANGELO MARIA (PC) |

**Neural prostheses (12 Cfu)**

- Cfu: 12
- Obiettivi formativi: The course on “Neural prostheses” is composed of two modules: “Neural interfaces and bioelectronic medicine” and “Neural tissue engineering”. During the course on “Neural interfaces and bioelectronic medicine” the students will acquire the basic principles underlying the design and development of implantable neural interfaces for different parts of the nervous system. They will also develop a broad view on existing neuroprosthetic systems to restore motor functions and on novel solutions based on the stimulation of the autonomic nervous system, and will be able to identify current limitations and challenges for future applications. Finally, the students will learn the conceptual and practical bases for the development of a novel neuroprosthesis (group project). During the course on “Neural tissue engineering” the students will acquire the strategies to develop grafts and scaffolds that can be implanted to promote nerve regeneration and to repair damage caused to nerves of both the central nervous system and peripheral nervous system by an injury and to eliminate inflammation and fibrosis upon implantation. Specifically, the technological processes and the materials necessary to realise these grafts and also their interaction with physiological neural tissue.
- Modalità di verifica finale: For Neural interfaces and bioelectronic medicine : Oral exam For Neural tissue engineering: project work and oral exam
- Propedeuticità e obblighi di frequenza : None

- Semestre: Annuale

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Neural interfaces and bioelectronic medicine | 6 | 60 | MICERA SILVESTRO |
| Neural tissue engineering | 6 | 60 | GIOVANNI VOZZI (80302) |

**Neuromorphic engineering (6 Cfu)**

- Cfu: 6
- Obiettivi formativi: The course will explore computational and physical models that emulate the neural dynamics of biological neurons of peripheral and central nervous system. A particular focus will be dedicated to real-time implementation of spiking artefacts that could be integrated in neurophysiological studies and in closed loop hybrid-bionic systems to restore missing sensorimotor functions.
- Modalità di verifica finale: project work and oral exam
- Propedeuticità e obblighi di frequenza : None

- Semestre: Primo semestre

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Neuromorphic engineering | 6 | 60 | 25973 ODDO CALOGERO MARIA (PC) |

**Principles of bionics engineering (6 Cfu)**

- Cfu: 6
- Obiettivi formativi: The course will introduce attendants to biological methods and systems found in nature which can be used as source of inspiration to study and design advanced engineering systems, technologies and algorithms. Examples will include: human and animal locomotion, biomechanics, sensorimotor control hypotheses and systems. The course will devote special attention to biomechatronic and biorobotic components and systems.
- Modalità di verifica finale: Oral exam
- Propedeuticità e obblighi di frequenza : None

- Semestre: Primo semestre

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Principles of bionics engineering | 6 | 60 | 13884 DARIO PAOLO (PC) |

**Prosthetics and rehabilitation robotics (12 Cfu)**

- Cfu: 12
- Obiettivi formativi: The course is composed of two modules: Artificial limbs and Robotic exoskeletons. The overall goal is to introduce students to the main challenges to design wearable powered robots for movement assistance, rehabilitation, augmentation and/or functional replacement. Along with the analyses of the main components involved in the development of an effective human-robot interaction, students will be engaged in laboratory and hands-on activities with working devices. In particular: Within the module “Artificial limbs” students will be introduced to and will experiment the architecture and function of the microcontroller. Within the module “Robotic exoskeletons” students will learn how to conceive, rapid-prototype and test multi-layered control architectures running on real-time targets endowed with FPGA processors.
- Modalità di verifica finale: Oral exam + projectual work.
- Propedeuticità e obblighi di frequenza : None

- Semestre: Secondo semestre

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Artificial limbs | 6 | 60 | CIPRIANI CHRISTIAN |

| | | | |
|---|---|---|---|
| Robotic exoskeletons | 6 | 60 | VITIELLO NICOLA |

**Robotics for assisted living (12 Cfu)**

- Cfu: 12
- Obiettivi formativi: The course “Robotics for assisted living” is composed by two modules: “Robot companions for assisted living” and “Cloud robotics”. The aim of the module “Robot companions for assisted living” is to present the main advanced technologies and methodologies to build robot companions for assisting people in daily life activities. It will focus on systems and services adequate to the end-users’ needs, adaptive to the environment and end-users’s behaviour, embedded not invasively in the environments, easily wearable by end-users, pro-active with Ambient Intelligence (AmI) capabilities and highly usable with advanced human machine interfaces. The main technological contents include wireless sensor network, wearable technology, service and cloud robotics. The module “Cloud robotics” will focus on the main basis for developing intelligent systems for Robot Companions applications. It will revolve around the analysis of middleware solutions for integration of smart environments and service robotics and the implementation of Wireless Sensor Network with the Microcontroller STM32W with ZigBee stack. Additionally it will introduce the main concepts of cloud computing and propose how to develop Cloud robotics applications.
- Modalità di verifica finale: Written exam
- Propedeuticità e obblighi di frequenza : None

- Semestre: Annuale

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Robot companions for assisted living | 6 | 60 | MAZZOLENI STEFANO |
| Cloud robotics | 6 | 60 | CAVALLO FILIPPO |

**Robotics for surgery and targeted therapy (12 Cfu)**

- Cfu: 12
- Obiettivi formativi: The course “Robotics for surgery and targeted therapy” is composed by two modules: “Robotics for minimally invasive therapy” and “Miniaturized therapeutic and regenerative systems”. The course of “Robotics for minimally invasive therapy” aims to provide students with methodology and guidelines to understand contribution and to exploit potentials of robotic technologies for minimally invasive therapy, diagnosis and surgery. The course will introduce different solutions for targeted therapies both minimally invasive and no invasive, e.g. which exploit external generators of therapeutic actions. At the end of the course the student will be able to identify the most appropriated targeting/therapeutic solutions for the different human body districts, at different scales, and for different pathologies. The course “Miniaturized therapeutic and regenerative systems” aims at providing students with the rationale, the methods and the most recent research advancements on milli, micro and nanosystems for achieving safe and effective targeted therapies. Bioengineering solutions for regenerative medicine, alternative to or synergic with traditional medical/surgical procedure, will be also highlighted. Where appropriate, hands-on activities will be included in the course, especially concerning micro/nano-fabrication and characterization techniques, biomaterial synthesis and functionalization and cell cultures.
- Modalità di verifica finale: For both modules Oral exam, including some design problems that the student should perform without the assistance of the professor during the exam. The students could be asked to prepare simple projectual works to be associated and evaluated together with the formal oral exam. The projectual works could combine competence acquired in Module 1 and Module 2.
- Propedeuticità e obblighi di frequenza : None

- Semestre: Annuale

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Robotics for minimally invasive therapy | 6 | 60 | 13301 MENCIASSI ARIANNA (PC) |
| Miniaturized therapeutic and regenerative systems | 6 | 60 | RICOTTI LEONARDO |

**Social robotics and affective computing (12 Cfu)**

- Cfu: 12
- Obiettivi formativi: The course is conposed of two modules “Social robotics” and “Affective computing” Social robotics is a fairly recent branch of robotics; it addresses the need for robots to correctly interpret people’s action and respond appropriately. Across point of several disciplines, such us psychology, engineering, sociology, social robotics development will be addressed in this course, with arguments mostly based on engineering reasoning and design. The course of Affective computing aims at showing how computational technology can be used to understand and interpret human emotions. Specifically, modelling of human emotional expression will be addressed, including software and hardware solutions to acquire, communicate, and express affective information. Understanding how emotions can be experienced can be also helpful to quantify correlated patterns of central and autonomic nervous activity in order to investigate on mood and consciousness disorders.
- Modalità di verifica finale: for both modules oral exam
- Propedeuticità e obblighi di frequenza : None

- Semestre: Annuale

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Social robotics | 6 | 60 | DANILO EMILIO DE ROSSI (05852) |
| Affective computing | 6 | 60 | ENZO PASQUALE SCILINGO (80193) |

**Statistical Signal Processing (6 Cfu)**

- Cfu: 6
- Obiettivi formativi: The course will cover statistical signal processing methods, with application to bioengineering field. The students will become familiar with basic concepts of discrete representation of deterministic and random continuous-time signals, discrete-time random signal analysis, deterministic and random parameter estimation. Various estimation methods will be introduced and compared, such as the method of moments, the

maximum likelihood and the linear and non-linear least squares methods. An introduction to Bayesian framework for random parameters and random signals estimation will be provided, with particular emphasis to the problem of linear smoothing, filtering, and prediction. Parametric auto-regressive moving average (ARMA) modeling and identification of discrete-time random signals will be also addressed. Advanced topics in parametric and non-parametric (adaptive and non-adaptive) methods for spectral estimation will be introduced, as well as some basic concepts of time-frequency analysis.

- Modalità di verifica finale: Written and oral exam
- Propedeuticità e obblighi di frequenza : None

- Semestre: Secondo semestre

**Moduli**

| Denominazione | Cfu | Ore didattica frontale | Docente |
|---|---|---|---|
| Statistical Signal Processing | 6 | 60 | FULVIO GINI (08329) |

### Gruppi Attività formative

**Free choice - List of classes that the student chooses freely. These classes will be automatically approved by the board of the Master Degree Course (cfu 12 )**

Economic assessment of medical technologies and robotics for healthcare (cfu 6)
Neuromorphic engineering (cfu 6)
Principles of bionics engineering (cfu 6)